Disentangling biotic and abiotic drivers of CO_2 flux in a drained German peatland using eddy covariance flux measurements and modelling techniques

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Biosphere-Atmosphere Interaction

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1. Introduction

- Peat lands store vast amounts of carbon, but drainage leads to oxidation of the organic material and release of greenhouse gas (GHG)
- Eddy covariance (EC) allows direct observation of net ecosystem gas exchanges (NEE) on the ecosystem scale
- NEE comprises of plant gross primary production (GPP) and total ecosystems respiration (Reco). Understanding these individually is crucial to upscale fluxes to larger timescales or areas
- Widely used techniques for partitioning NEE to GPP and Reco leave out factors such as the effect of soil water content on respiration or changes in phenology. Additionally, recent literature raises doubt on the daily unimodal respiration cycle in peatlands[1] assumed in respiration models

2. Research Goals

a) Quantify CO_2 fluxes in this peatland

b) Evaluate the feedback of NEE to environmental drivers on different time scales

c) Outlook: Make use of phenological and abiotic observations to constrain GPP and Reco from NEE using a combination of data and mechanistic modeling

3. Site & Methods

Site: Drained bog in Amtsvenn, NW-Germany with an intact peat column of 3 m depth. Water table depth fluctuates between 70 cm (Sep.) and 15 cm (April). Vegetation comprises mainly of grass, dwarf shrubs and birches

Instrumentation: EC tower (Fig. 1), 2 soil profiles, PhenoCam, various meteorological sensors (Table 1) – since Oct. 2022

Singular Spectrum Analysis (SSA): A PCA-like method to deduce leading components in 1-D time series datasets[2]

Table 1: Deployed instruments and measured variables in Amtsvenn

Eddy Covariance	CO_2 and H_2O flux, 3D - wind speeds/directions
Meteorological	Air temperature (Ta), rel. humidity, short/long wave radiation, photosynth. photon flux density (PPFD), precipitation
Soil Profiles, 5cm depth	Soil water content (SWC), -temperature (Ts), and -heat flux

Figure 1: Eddy Covariance tower at the Amtsvenn peatland, NW-Germany

4. Preliminary observations

a)

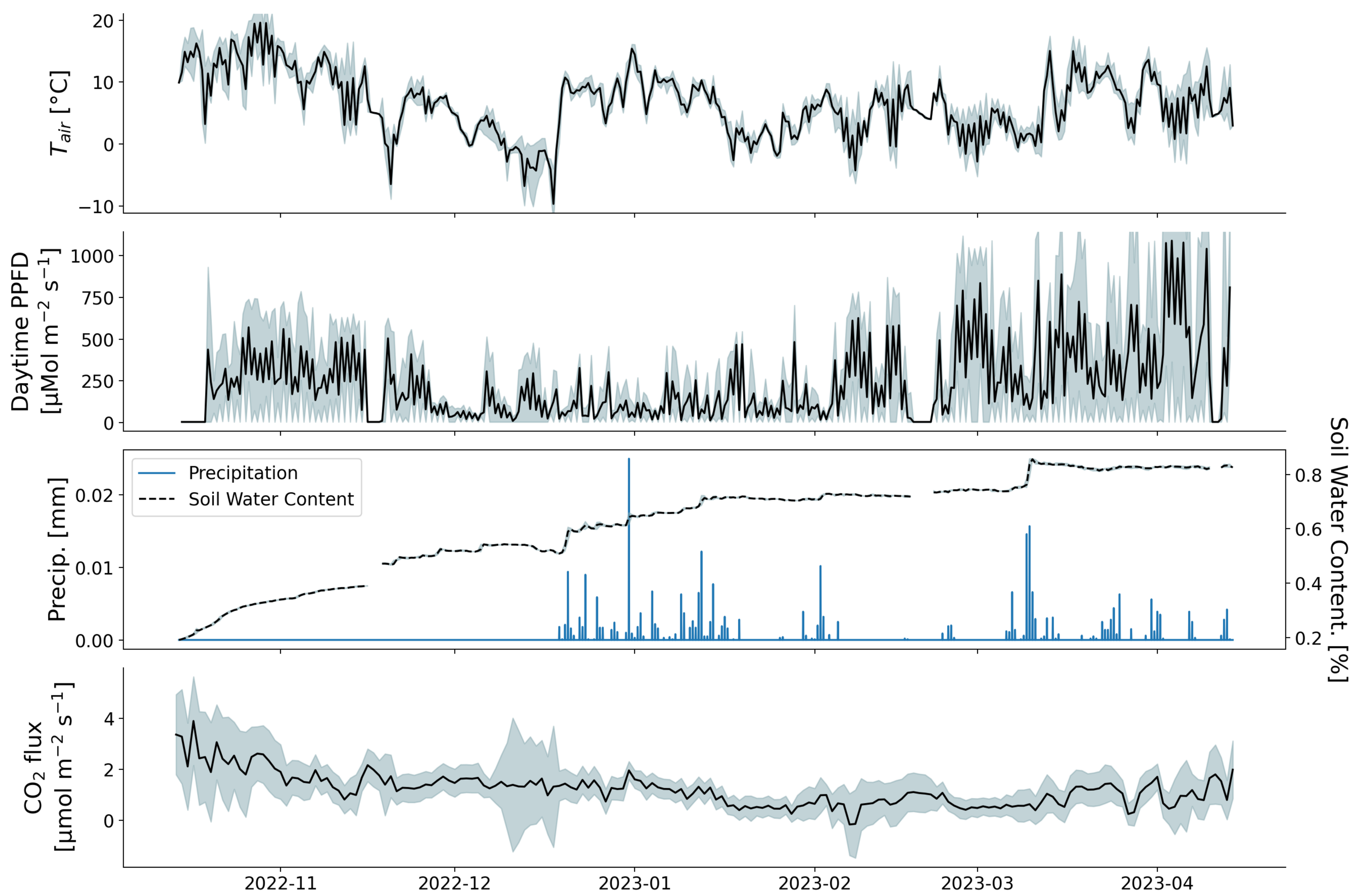

Figure 2: Time series of daily averaged environmental variables and CO_2 flux (NEE). Shaded areas show the minimum and maximum values. For CO_2 flux the daily avg. ± standard deviation is shown.

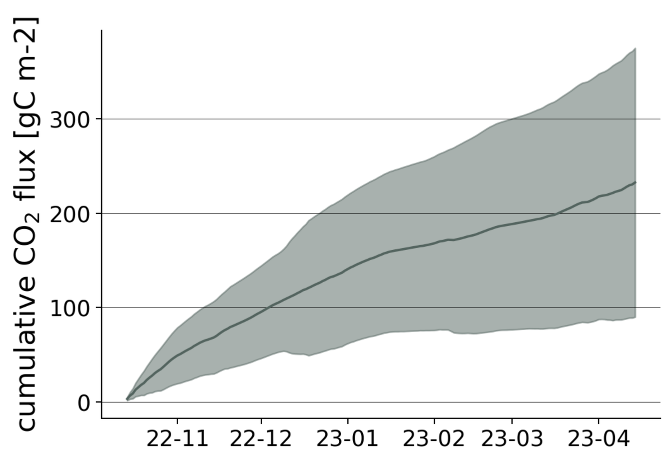

Figure 3: Cumulative CO_2 flux over the period 15.10.23-14.04.2023.

- Total NEE for the measured period amounts to 232 ± 142 gC m^{-2} (Fig. 3)
- Flux uncertainties due to low fluxes in wintertime and uncertainty of MDS gap-filling[4] (Fig. 2)
- Extending the measurements presumably will reduce gap-filling errors

b)

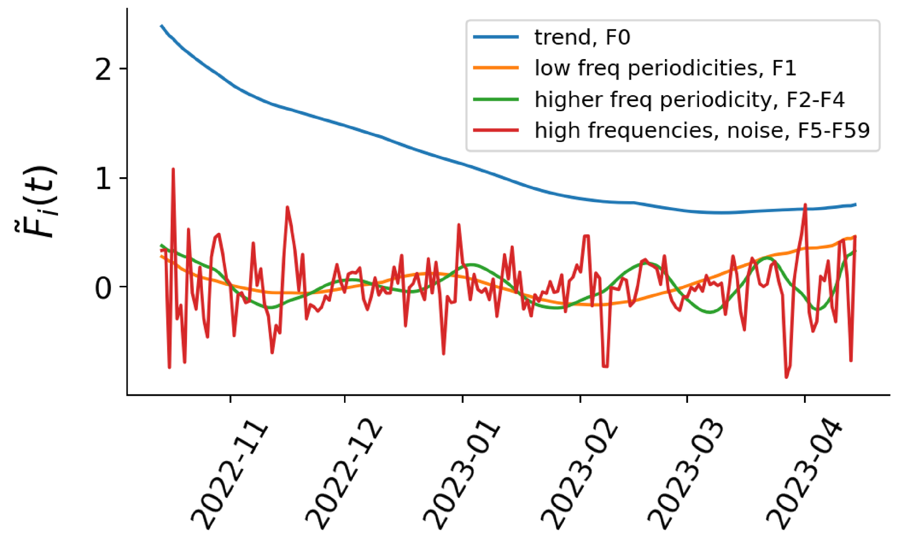

Figure 4: Decomposed and grouped components of daily NEE. The window-length was chosen as 59 due to the first minimum in time-series autocorrelation at this lag[2]

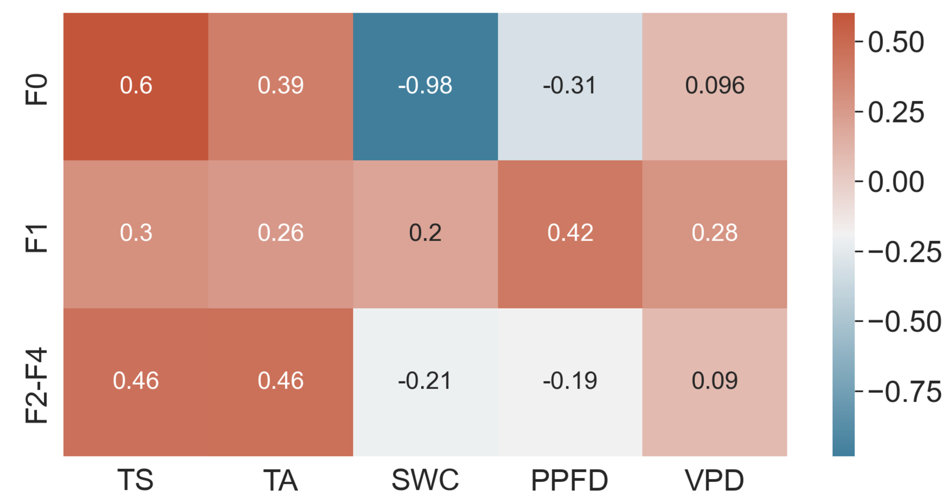

Figure 5: Correlation of environmental drivers with the grouped decomposed components of daily NEE

- A strong trend component (F0) is clearly separable (Fig. 4) and explains > 60% of the variance in NEE
- This first component correlates almost 1:-1 with soil moisture (Fig. 2, 5), all components correlate with Ta and Ts
- This gives confidence in a strong control of SWC besides Ta and Ts on NEE dynamics
- Correlation of PPFD with F1 hints towards a biotic control

5. Outlook

c)

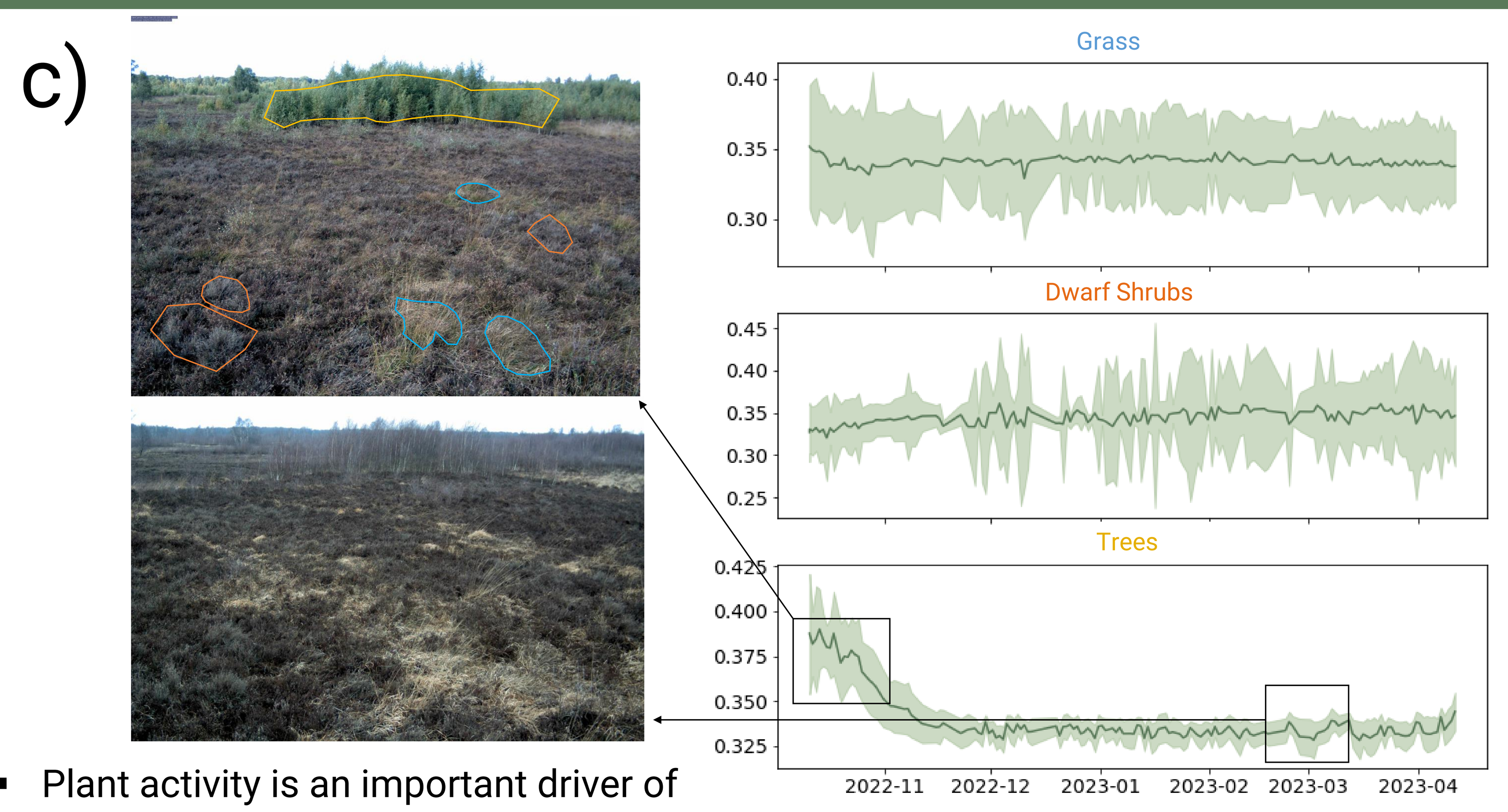

Figure 6: Time series of GCC for different plant types. Colors of headings correspond to the masks in the digital images on the left

- Plant activity is an important driver of NEE and can be continuously approximated from green chromatic coordinate (GCC) data from PhenoCam images[3]
- We constructed time series of GCC for separate plant species (Fig. 6)
- A LIDAR-based vegetation microform map shows vegetation distribution in the flux footprint (Fig. 7)
- We aim to improve partitioning of NEE based on this information

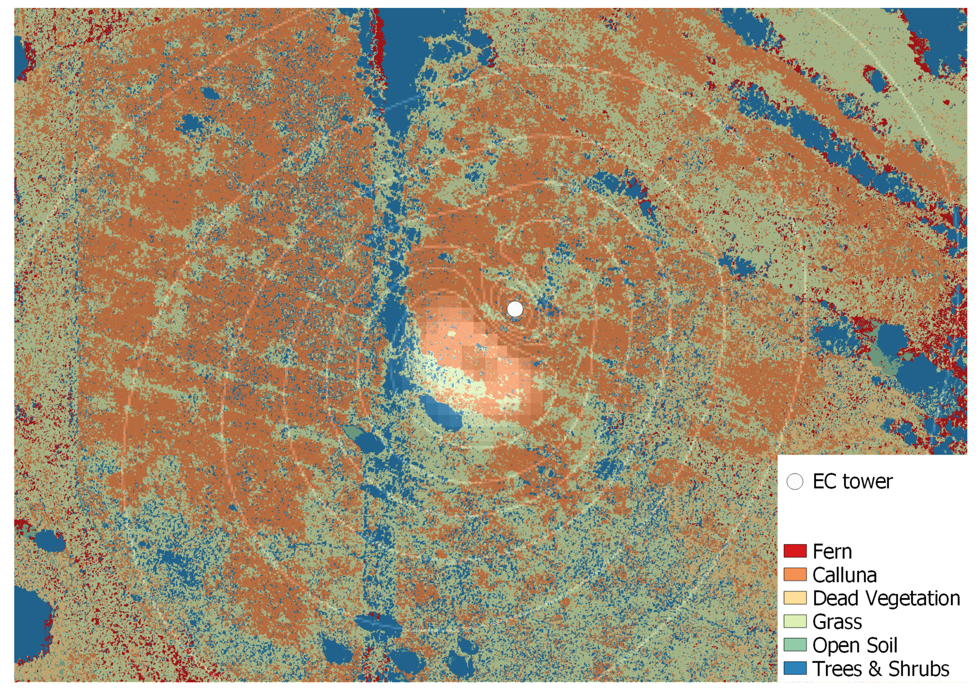

Figure 7: Map of vegetation distribution in Amtsvenn. Light circles show the 10% flux contribution lines in the footprint of the EC tower

[1]Järveoja, J., Nilsson, M.B., Crill, P.M. *et al.* Bimodal diel pattern in peatland ecosystem respiration rebuts uniform temperature response. *Nat Commun* **11**, 4255 (2020).
[2]Wang, R., Ma, H., Liu, G., & Zuo, D. C. Selection of window length for singular spectrum analysis. *Journal of the Franklin Institute-engineering and Applied Mathematics,* **352(4)**, 1541–1560 (2015)
[3]Järveoja, J, Nilsson, MB, Gažovič, M, Crill, PM, Peichl, M. Partitioning of the net CO_2 exchange using an automated chamber system reveals plant phenology as key control of production and respiration fluxes in a boreal peatland. *Glob Change Biol*. **24**: 3436– 3451 (2018)
[4]Aubinet, M., Vesala, T., and Papale, D.: Eddy Covariance: A Practical Guide to Measurement and Data Analysis, Springer, Dordrecht, the Netherlands, (2012)